(12) UK Patent Application (19) GB (11) 2 344 691 (13) A

(43) Date of A Publication 14.06.2000

(21) Application No 9827328.7

(22) Date of Filing 12.12.1998

(71) Applicant(s)
Sharp Kabushiki Kaisha
(Incorporated in Japan)
22-22 Nagaike-cho, Abeno-ku, Osaka 545-8522, Japan

(72) Inventor(s)
Judy Megan Rorison
Harald Reinhart Bock
Michael John Towler
Michael Stuart Weaver
Andrew James Hudson
Yoshimasa Fujita
Sally Anderson

(74) Agent and/or Address for Service
Marks & Clerk
4220 Nash Court, Oxford Business Park South,
OXFORD, OX4 2RU, United Kingdom

(51) INT CL[7]
H05B 33/14, H01L 33/00 51/20 51/40

(52) UK CL (Edition R)
H1K KEAL K1EA K2R4

(56) Documents Cited
GB 0788479 A EP 0786820 A EP 0712024 A
WO 98/35393 A WO 97/07654 A WO 96/03015 A

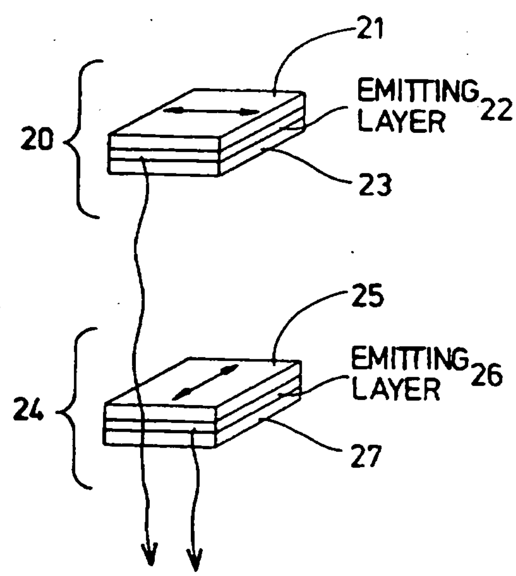
(58) Field of Search
UK CL (Edition Q) H1K KEAL KEAM
INT CL[6] G02F 1/1337, H01L 33/00 51/00 51/10 51/20 51/30 51/40, H05B 33/12 33/14 33/20
online: EPODOC,WPI,JAPIO,INSPEC

(54) Abstract Title

An electroluminescent device

(57) An electroluminescent device has at least first and second light-emitting regions (22,26). The emitter molecules in the first light-emitting region (22) are aligned substantially in a first direction and the emitter molecules in the second light-emitting region (26) are aligned substantially in a second direction, the first direction being different from the second direction. As a consequence of the alignment of the emitter molecules, the first light-emitting region (22) emits light having a first polarisation and the second light-emitting region (26) emits light having a second, different polarisation. Alternatively or in addition, the emitted light may have different wavelengths. Techniques for making the regions (22,26) are described, e.g. by aligning the emitter molecules within a fluid matrix and then fixing the matrix, and by evaporating the emitter molecules perpendicularly onto an alignment layer which itself has been evaporated obliquely onto a substrate.

FIG 3



GB 2 344 691 A

At least one drawing originally filed was informal and the print reproduced here is taken from a later filed formal copy.

FIG 1

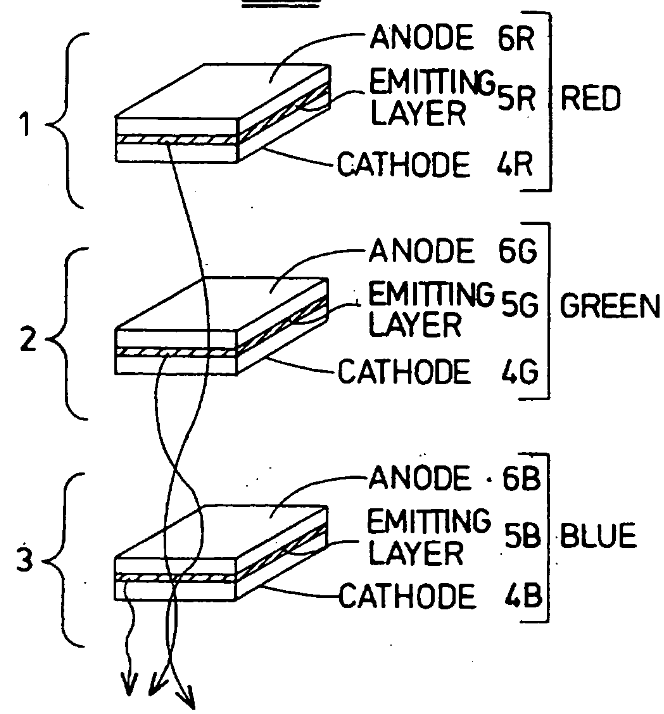


FIG 2

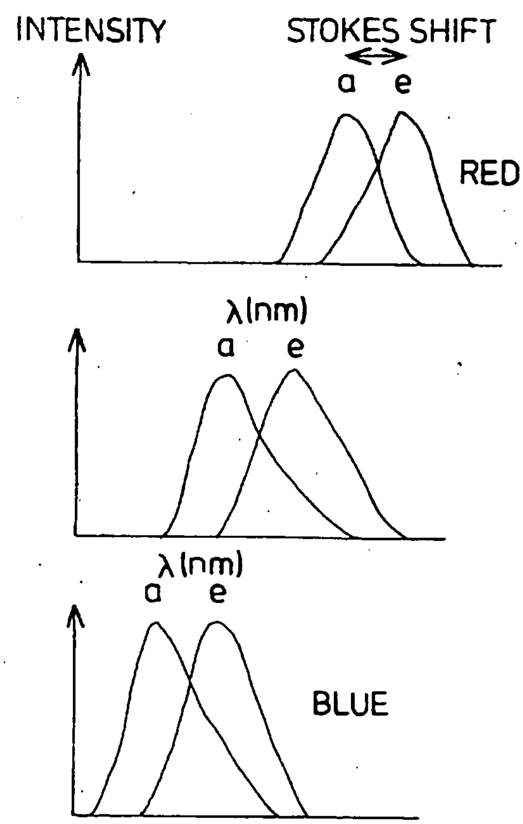


FIG 3

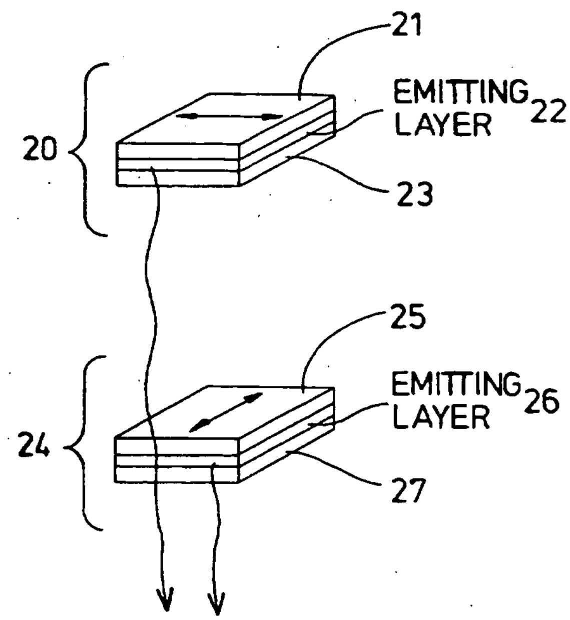


FIG 4

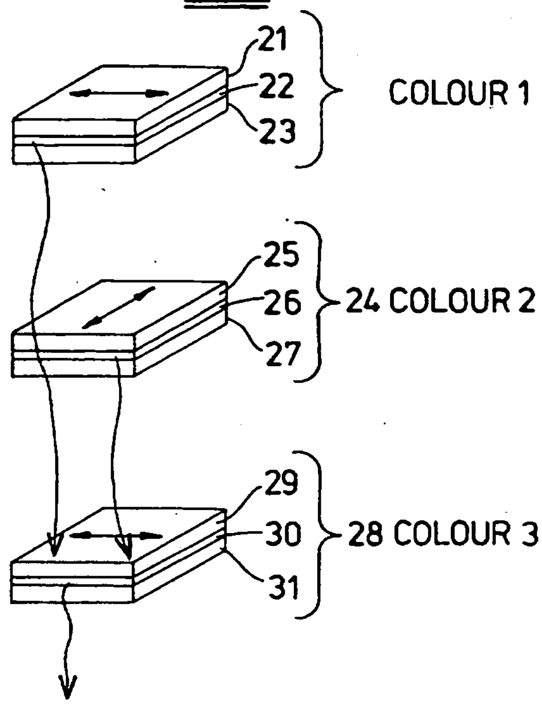

21
22
23
COLOUR 1
25
26
27
24 COLOUR 2
29
30
31
28 COLOUR 3

FIG 6

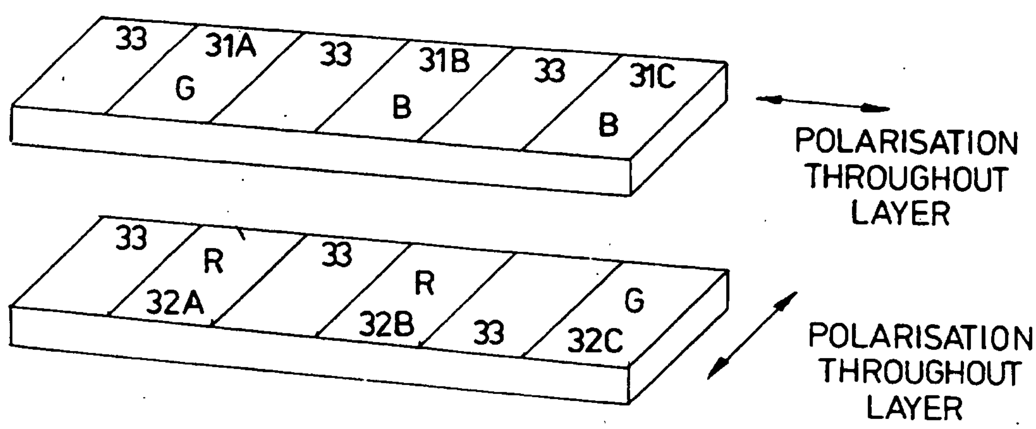

33
31A
G
33
31B
B
33
31C
B
POLARISATION THROUGHOUT LAYER
33
R
32A
33
R
32B
33
G
32C
POLARISATION THROUGHOUT LAYER

FIG 5a

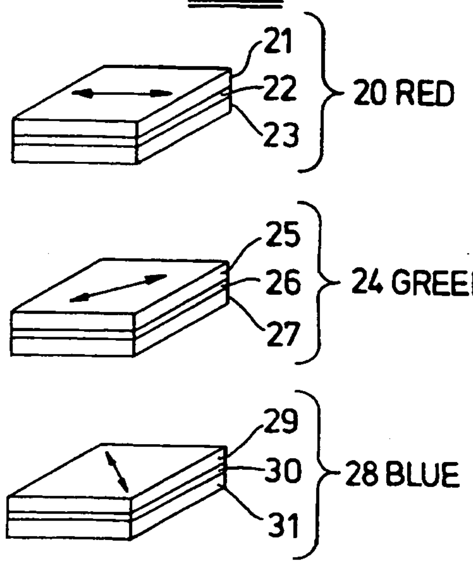


FIG 5b

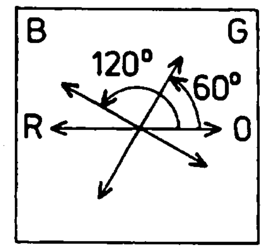


FIG 7

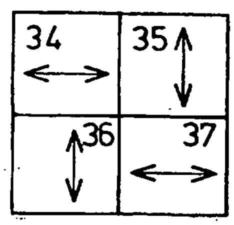


FIG 8

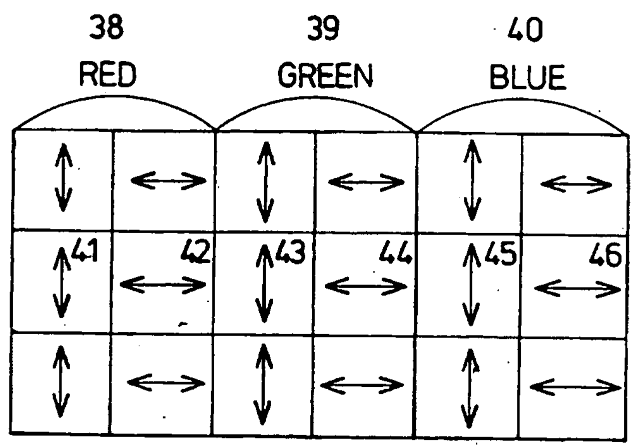


FIG 10

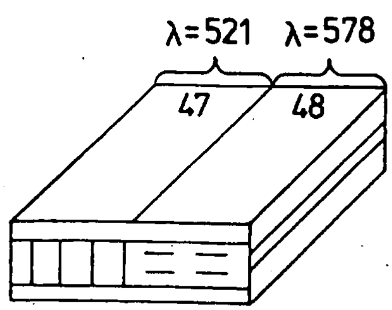


FIG 9a

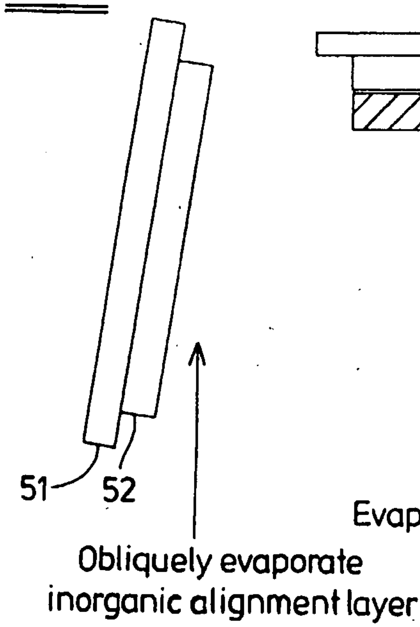


FIG 9b

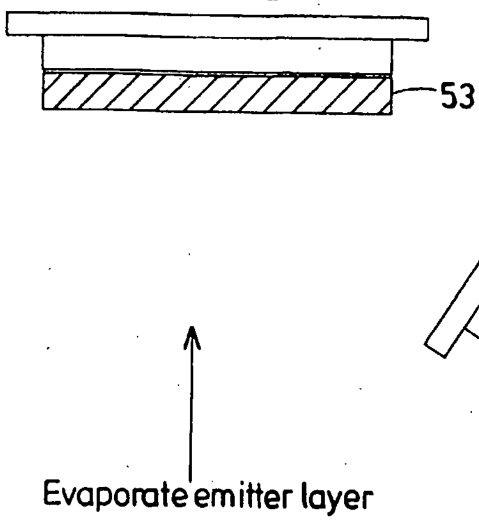


FIG 9c

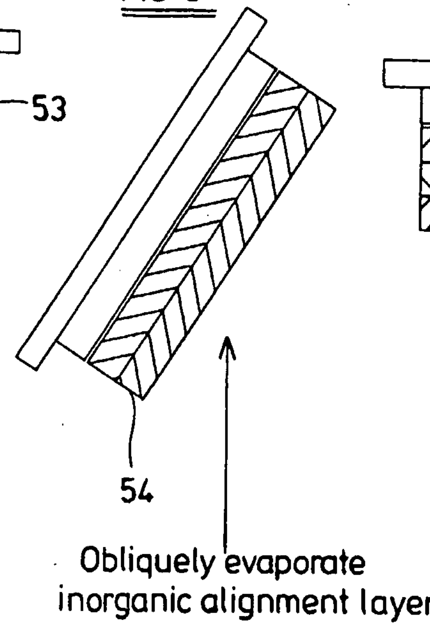


FIG 9d

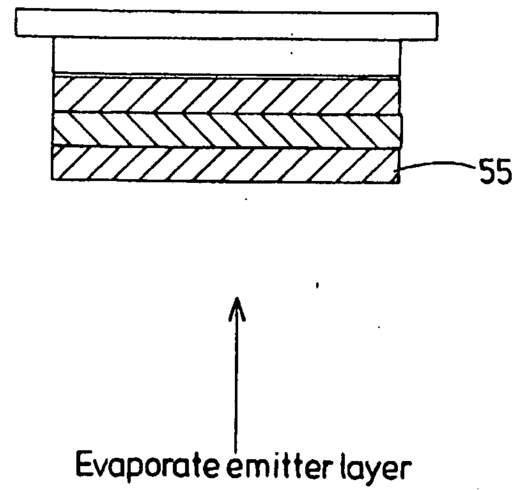


FIG 9e

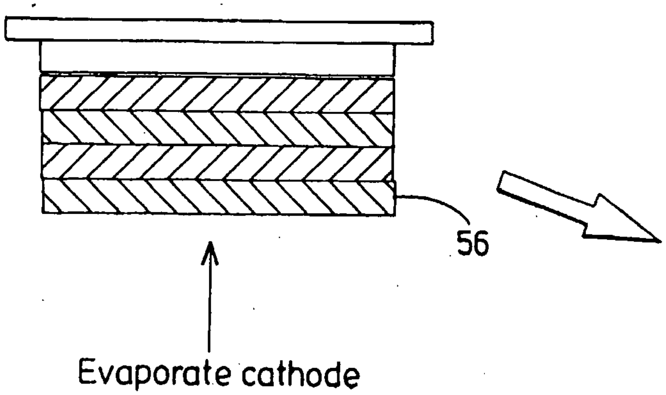


FIG 9f

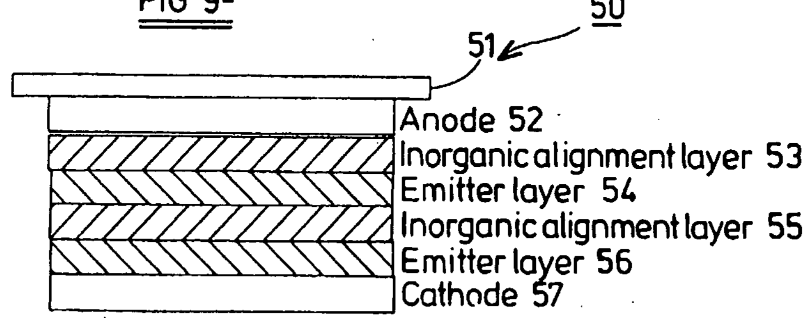
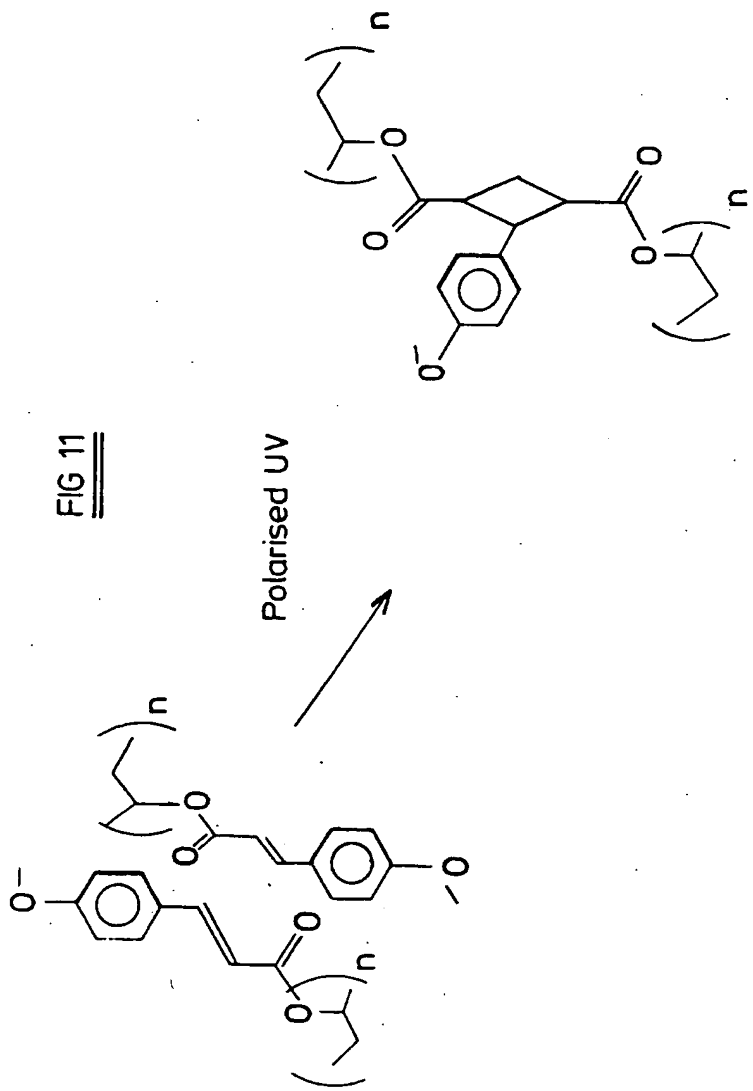


FIG 11



An Electro Luminescent Device

The present invention relates to an electroluminescent device. In particular, it relates to an electroluminescent device which has two or more light-emitting regions.

An electroluminescent ("EL device") generates light as a result of electron - hole recombination. An EL device typically has a multilayer structure, in which a light-emitting layer is confined between an anode layer and a cathode layer The emitter layer may be either an organic material or an inorganic material. Charge carrier recombination occurs in the emitter layer, and photons are generated. It is possible to vary the wavelength of light emitted by an EL device by using different materials for the emitter layer or by applying different drive conditions to the emitter layer, and it is also possible to manufacture an EL device that emits white light.

Many organic emitting materials have relatively broad emission and absorption spectra. If single colour emission, or a narrow colour range, is required, it is possible to use colour filters as disclosed in J. Kido et al, "Science" Vol 267, page 1332 (1995). An alternative approach to obtaining a narrow wavelength range is to use cavity effects to narrow the emission spectrum, as described A. Dodabalapur et al, "Journal of Applied Physics" Vol 80, page 6954 (1996). Although the output wavelength can be narrowed using cavity effects, this approach has the disadvantage that the output becomes very directional and this is undesirable in a display intended to be viewed from a wide range of angles.

In many applications it is desirable to provide a full colour display. One possible way to achieve a full colour EL device involves dividing each pixel into three sub-pixels, with the three sub-pixels lying side by side. One of the sub-pixels emits red light, one green light and one blue light. A device of this type is disclosed in US Patent No. 5 294 869. One disadvantage of this known device is that each colour is emitted from only one third of the total active area of the device, so that the intensity of the device is low.

An alternative approach to providing a full colour EL device consists of stacking two or more EL devices above one another. Devices of this type are disclosed in P. E. Burrows et al, "Applied Physics Letters" Vol 69, No. 20, 11 November 1996, pages 2959-2961, and in S. R. Forrest et al. "Synthetic Metals" Vol. 91, pages 9-13 (1997).

A stacked, three-layer EL device is shown schematically in Figure 1. This consists of a red EL element 1 disposed over a green EL element 2 which in turn is disposed over a blue EL element 3. Each EL element comprises a cathode layer 4B, 4G, 4R, an emitter layer 5B, 5G, 5R, and an anode layer 6B, 6G, 6R. Although Figure 1 shows the EL elements as being separate from one another, in practice they would be stacked with an insulating layer separating each anode-cathode interface.

In the stacked EL device shown in Figure 1, emission of light of each colour occurs over the entire active cross-sectional area of the device, so that the intensity of the device is improved compared to the device described above which uses laterally divided sub-pixels. However, the EL device shown in Figure 1 has the disadvantage that light emitted by the red EL element must pass through the other two elements before it is emitted from the device, and that light emitted from the green EL device must pass through the blue EL device. This is a particular problem if organic materials are used to form the emitter layers in the EL elements, since organic emitting materials generally have relatively broad emission and absorption spectra.

Forrest et al have attempted to address the problem of light emitted in one EL element being absorbed in a subsequent EL element. They have made use of the Stokes effect which provides a shift between the peak emission wavelength and the peak absorption wavelength.

The Stokes shift is illustrated in Figure 2, which shows the emission and absorption spectra for the three EL elements of the EL device of Figure 1. The letter "a" indicates the absorption spectra, and the letter "e" indicates the emission spectra. The Stokes shift appears as a shift between the absorption spectrum and the emission spectrum for an EL emitter layer. Forrest et al have chosen materials which have large Stokes shifts

so as to minimise the absorption of radiation emitted by one EL element in other EL elements.

The devices proposed by Forrest et al have the following disadvantages. Firstly, the choice of materials for the emitter layers of the EL elements is restricted, owing to the need to use only materials with a large Stokes shift. Moreover, Forrest et al are constrained to use the particular order of the red, green and blue EL elements shown in Figure 1, so that the red light (with a low energy) subsequently passes through emitter layers having a higher band gap. However, even if the red light is not absorbed across the band gap of the emitter layers in the green and blue EL elements, some absorption of the red light will inevitably occur as it passes through the blue and green EL elements. The red EL element currently has the lowest intensity of the red, green and blue EL elements. It would thus be preferable to put the red EL element to the front so that the red light did not have to pass through the green and blue EL elements, rather than place it at the back as required by Forrest et al.

A further disadvantage with the prior art is that the EL devices will emit light in both the forward direction (as shown in Figure 1) and in the backward direction. It would be desirable to utilise the light emitted in the backward direction, as well as the light emitted in the forwards direction, so as to increase the intensity of the device. It is possible to provide a mirror (not shown) above the red EL element of Figure 1 to reflect the light emitted in the backward direction back towards the blue EL element 3. However, light emitted in the backwards direction by the green or blue EL elements will have to pass through the red EL element twice, once before it reaches the mirror and once after it has been reflected, so that significant absorption will occur. Thus, even if a mirror is provided much of the light emitted in the backward direction will be lost.

In an EL device having an organic emitting layer, the emitting layer is usually evaporated, or spun-down. This will produce an amorphous emitting layer, which emits light having no polarisation. In many applications, it would be desirable to produce an organic EL device that emits polarised light.

One known approach to providing an organic EL device that emits light having some degree of polarisation is to deposit the organic emitting layer with some degree of orientation. This can be done by techniques such as Langmuir-Blodgett deposition, mechanically deforming an organic emitting layer, or rubbing a pure conjugated - polymer emitter layer. An alternative technique is to deposit a polymer layer on a highly aligned orientation layer such as polytetrafluoroethylene or polyimide, or by stretching a polymer layer. A further known technique is disclosed by Weder et al in "Advanced Materials" Vol. 9, page 1035 (1997), in which they disclose the tensile deformation of a guest-host system, so that the guest molecules adopt the orientation of the host.

An alternative approach to providing an organic emitting layer that emits light having some degree of polarisation is the cross-linking of polymeric materials using polarised UV light. This method eliminates the mechanical rubbing step, which is desirable since rubbing may introduce charge, inhomogeneities and dirt into the organic layer. M. Hasegawa et al, "J Photopolym Sci Technol" Vol. 8, page 241 (1995), M. Schadt et al, "Japanese Journal of Applied Physics" Vol. 31, page 2155 (1992) and M. Schadt et al, "Nature" Vol. 381, Page 212 (1996) disclose studies on cross-linking by polarised UV light.

A first aspect of the present invention provides an electroluminescent device having first and second light-emitting regions, wherein the emitter molecules in the first light-emitting region are aligned substantially in a first direction and the emitter molecules in the second light-emitting region are aligned substantially in a second direction, the second direction being different from the first direction. The first light-emitting region may emit, in use, light having a first polarisation and the second light-emitting region may emit, in use, light having a second polarisation different from the first polarisation. The polarisation of the emitted light arises from the alignment of the emitter molecules, and the difference in polarisation between light emitted from the first and second light-emitting regions is due to the different alignment directions in the two light-emitting regions.

The first and second light-emitting regions may be arranged to emit plane-polarised light. The plane of polarisation of light emitted by the first light-emitting region may be at an angle of substantially 90° to the plane of polarisation of light emitted by the second light-emitting region. Light emitted by the first light-emitting region will not be significantly absorbed in the second light-emitting region, so that light losses in a stacked EL device are reduced.

Alternatively, the first light-emitting region may emit light having a different wavelength to light emitted by the second light-emitting region. The wavelength difference arises because of the different alignment directions of the emitter molecules in the first and second regions. If the first and second emitter regions can be controlled independently, then the output wavelength of the device can be easily changed.

The first and second light-emitting regions may be disposed side by side. Alternatively, the first light-emitting region may be disposed over the second light-emitting region. The electroluminescent device may further comprise a third light-emitting region, with the first light-emitting region disposed over the second light-emitting region, and the second light-emitting region being disposed over the third light-emitting region.

The third light-emitting region may emit polarised light having a third polarisation which is different from at least one of the first and second polarisations. The first, second and third light-emitting regions may emit plane-polarised light, with the plane of polarisation of the light emitted by the second light-emitting region being at substantially 60° to the plane of polarisation of the light emitted by the first light-emitting region, and the plane of polarisation of light emitted by the third light-emitting region may be at substantially 120° to the plane of polarisation of light emitted by the first light-emitting region. This will again reduce absorption of light emitted by the first light-emitting region as it passes through the second and third light-emitting regions, and will also reduce the absorption of light emitted by the second light-emitting region as it passes through the third light-emitting region.

A second aspect of the present invention provides an electroluminescent device having first and second light-emitting regions, with the first light-emitting region emitting light having a first polarisation and the second light-emitting region emitting light having a second polarisation different from the first polarisation.

A third aspect of the present invention provides a method of manufacturing an emitter region for an electroluminescent device, the method comprising the steps of: -

disposing emissive molecules in a fluid matrix; aligning the emissive molecules within the matrix; and fixing the matrix so as to hold the alignment of the emissive molecules within the matrix. This provides a simple method of producing an organic emitter layer in which the emitter molecules are aligned.

The step of aligning the emitter molecules may comprise applying an electric field, or it may comprise applying a magnetic field.

The step of fixing the matrix may comprise fixing only a selected portion of the matrix. This allows the emitter molecules in the selected portion to be aligned in one direction, and emitter molecules in other portions of the matrix can then be aligned in another direction.

A fourth aspect of the present invention provides a method of manufacturing an emitter region for an electroluminescent device, the method comprising the steps of: evaporating an alignment layer over a substrate, the direction of evaporation being oblique to the substrate; and evaporating emissive molecules onto the alignment layer so as to form the emitter layer, the direction of evaporation of the emissive molecules being substantially perpendicular to the substrate.

The orientation of the molecules in the emitter layer will be controlled by the alignment direction of the alignment layer, and this will depend on the angle between the evaporation direction and the substrate when the alignment layer is evaporated. This method can be used to manufacture a stacked EL device having two (or more) emitter

layers with the emitter molecules in one emitter layer being aligned in a different direction from the emitter molecules in the other emitter layer, by growing each emitter layer over an obliquely deposited alignment layer.

Preferred embodiments of the present invention will now be described by way of illustrative examples with reference to the accompanying Figures in which: -

Figure 1 is a schematic sectional view of a prior art three-layer electroluminescent device;

Figure 2 shows the absorption and emission spectra for the three EL elements of the device of Figure 1;

Figure 3 is a schematic view of an EL device according to a first embodiment of the invention;

Figure 4 is a schematic view illustrating a three-layer EL device according to another embodiment of the present invention;

Figure 5a shows a modification of the embodiment of Figure 4;

Figure 5b shows the polarisation directions for the three EL layers of the device of Figure 5a;

Figure 6 shows an EL device according to a further embodiment of the present invention;

Figure 7 is a schematic plan view of an EL element according to a further embodiment of the invention;

Figure 8 is a schematic plan view of an EL element according to a further embodiment of the present invention;

Figures 9a to 9f show steps in the manufacture of a stacked EL element according to the invention;

Figure 10 is a schematic plan view of an EL element capable of emitting light at two different wavelengths according to a further embodiment of the present invention; and

Figure 11 is a schematic illustration of the polymerisation of a cinnamate polymer.

Figure 3 is a schematic illustration of a two-layer EL device according to the present invention. It has a first EL device 20 comprising an anode 21, an emitting layer 22, and a cathode layer 23. This is disposed over a second EL device 24 which consists of an anode layer 25, an emitter layer 26 and a cathode layer 27.

The two emitter layers 22, 26 may emit light of different wavelengths, or of the same wavelength. The two emitter layers can be controlled independently from one another.

The emitter layers 22, 26 emit light that is substantially plane-polarised (this will hereinafter be referred to as "plane-polarised light" for convenience). The plane of polarisation of the light emitted by the emitter layer 22 is at 90° to the plane of polarisation of light emitted by the emitter layer 26 of the second EL element 24.

The polarisation of the emitted light is achieved by orienting the light-emitting molecules within an emitter layer so that they are all aligned in substantially the same direction within the plane of the emitter layer. The electric field director of the plane-polarised light will be perpendicular to the direction of the alignment of the emitter molecules.

An emitter molecule is not able to absorb light whose electric field director is parallel to its length. Thus, in the device shown in Figure 3, the emitting molecules in the emitter layer 26 of the second EL element will not be able to absorb the light emitted by the first EL element, since this is plane-polarised at 90° to their absorption direction. In

consequence, the absorption of light emitted by the first EL element 20 in the emitter layer of the second EL element 24 will be eliminated or, at least greatly reduced.

The present invention has a number of advantages over the prior art. Firstly, since the absorption of light emitted by one EL element in another EL element is substantially prevented by polarising the light, there is no need to restrict the choice of the emitter layers to materials with large Stokes shifts as in Forrest et al. This means that many more materials can be used in the EL elements.

Moreover, in a case where the EL elements emit light with different wavelengths, there is no need to place the long wavelength EL element behind the short wavelength EL element. Thus, a red EL element can be placed at the front of the device and this, as noted above, is desirable since red EL elements tend to be less intense than EL elements emitting light of other wavelengths.

Since absorption of light emitted by one EL element in the other EL element is prevented by the polarisation of the light, it is even possible for the two EL elements to emit light at the same wavelength. Since the two EL elements are independently controllable, this would produce a device for emitting polarised light, with the capability of easily changing the polarisation state of the output light.

Since light emitted by one EL element is not absorbed by the other EL element owing to the polarisation of the light, it is now possible to utilise the light emitted in the backwards direction by providing a mirror at the back of the device.

The present invention is not limited to a two-layer EL device, but can be applied to EL devices having three or more layers. An example showing the invention applied to a three-layer EL device is shown in Figure 4. Compared with the device shown in Figure 3, the device shown in Figure 4 additionally comprises a third EL element 28, having an anode layer 29, an emitter layer 30 and a cathode layer 31. The three EL elements can be controlled independently, to give a full-colour display.

The emitter layer 30 is arranged to emit light that is plane-polarised in the same direction as the light emitted by the emitter layer 22 of the first EL element 20, and which is plane-polarised at 90° to the plane of polarisation of light emitted by the emitter layer 26 of the second EL element 24. Because of the different directions of polarisation, the green emitter layer is not able to absorb the red light emitted by the red EL device, and the blue emitter layer is not able to absorb any green light emitted by the green EL element. It is possible, however, for the blue emitter layer to absorb light emitted by the red EL element, since the red emitter layer 22 and the blue emitter layer 30 are arranged to emit light that has the same direction of polarisation. However, as shown in Figure 2, the emission spectrum for the red emitter layer is sufficiently far removed from the absorption spectrum for the blue emitter layer so that there is unlikely to be significant absorption of red light in the blue emitter layer.

A suitable material for the emitter layer of the green EL element is PPV. A suitable material for the emitter layer of the red EL element is DCM/NIR in PPV. (DCM is 4-(dicyanomethylene)-2-methyl-6-(4-dimethyl-6-(4-dimethylaminostyrl))-4H-pyran, and NIR is Nile Red.) A suitable emitter material for the blue EL element is distyrlybenzene in polycarbozole.

An alternative arrangement for a three-layer EL device is shown schematically in Figure 5a. As with the device of Figure 4, this consists of a red EL element 20, a green EL element 24, and a blue EL element 28. The emitter layers 22, 26 and 30 of the three EL elements are again arranged to emit plane-polarised light.

In the embodiment of Figure 5a, the emitter layer 26 of the green EL element 24 is arranged to emit light that is plane-polarised at 60° to the direction of the plane-polarised light emitted by the emitter layer 22 of the red EL element. The blue EL element 28 emits light that is plane-polarised at 60° to the plane of polarisation of the light emitted by the green EL element 24, and at 120°C to the plane of polarisation of light emitted by the red EL element 20. The polarisations of the red, green and blue light emitted by the three EL elements are shown schematically in Figure 5b.

Since the planes of polarisation of the red and green light are not orthogonal, there will be some slight absorption of red light in the emitter layer 26 of the green EL element. However, this will be reduced by a factor of approximately $\cos^2 60$ - that is, to approximately one quarter of the absorption that would occur in the case where the EL elements emitted unpolarised light. Similarly, the emitter layer 30 of the blue EL element will absorb both red and green light, but this absorption will be reduced by a factor of $\cos^2 60$ compared to a case where amorphous emitter layers were used.

Whether the arrangement shown in Figure 4 or the arrangement shown in Figure 5a is preferable will depend on factors such as the relative intensities of the three EL elements.

A further embodiment of the invention is shown in Figure 6. This is a two-layer device, which consists of a first EL element 31 disposed over a second EL element 32. Each of the EL elements is laterally sub-divided into three light-emitting areas. The first EL element 31 has a light-emitting area 31A that emits green light, and two areas 31B, 31C which emit blue light. The second EL element 32 has two areas 32A, 32B which emit red light and an area 32C which emits green light. The two EL elements are arranged such that the light-emitting areas of the first EL element are placed directly over the light-emitting areas of the second EL element 32. Adjacent light-emitting areas of each EL element are separated by a non-emissive region 33. The light-emitting areas are independently controlled.

As indicated in Figure 6, the two EL elements are both arranged to emit plane-polarised light, with the light emitted by the first EL element 31 being polarised at 90° to the light emitted by the second EL element 32. This means that light emitted by one EL element will not be absorbed in the emitter layer of the other EL element.

Figure 7 shows a further embodiment of the present invention. This is a one-layer EL element, in which the emitter layer is divided into four emissive regions 34, 35, 36, 37. The emissive regions all emit plane-polarised light, but two of the regions 34, 37 emit light that is plane-polarised in one direction, and the other two regions 35, 36 emit light

that is plane-polarised at 90° to the direction of polarisation of light emitted by the regions 34, 37. The four emissive regions 34, 35, 36, 37 are controllable independently from one another. This means that the polarisation of the light from the EL element can be changed easily, for example by switching emissive regions 34, 37 OFF and switching emissive regions 35, 36 ON.

A related embodiment is shown in Figure 8. This is a one - layer EL element, in which the emissive layer has a red emissive region 38, a green emissive region 39, and a blue emissive region 40. The red, green and blue emissive regions, in turn, are divided into regions 41, 43, 45 which emit light plane-polarised in one direction and other regions 42, 44, 46 which emit light plane-polarised in an orthogonal direction. Thus, the EL device shown in Figure 8 provides a full-colour output, the polarisation state of which can easily be varied. Such an EL element could be used in, for example, a 3-D display device.

One method of producing an EL element having an emissive layer in which the emissive molecules are aligned in a particular direction consists of suspending the emissive molecules in a fluid such as reactive mesogen RM257 (available from Merck Ltd). Next, the molecules are oriented so that they are all aligned in a particular direction. This can be done, for example, by applying an electric field or a magnetic field. The fluid matrix is then "fixed", so that the emissive molecules are no longer able to move within the matrix. The matrix can be fixed by, for example, irradiating the matrix with UV light. Thus, the alignment direction of the emissive molecules within the matrix is set. The electric or magnetic field can then be removed.

As an alternative to fixing the entire fluid matrix, it is possible to fix just selected parts of the fluid matrix. This can be done, for example, by irradiating the fluid matrix through a mask pattern, so that only selected areas are irradiated. The device illustrated in Figure 7 could be produced by applying an electric field to align the emissive molecules in the directions required in the regions 34 and 37, and then irradiating only the areas 34, 37 to fix the matrix in these regions. The direction of the applied electric

field is then changed, to orient the emissive molecules in the region 35, 36 correctly, after which the regions 35, 36 are irradiated so as to fix the matrix in these areas.

One possible method of manufacturing a stacked EL element in which the emissive molecules in different EL layers are oriented in different directions will now be described with reference to Figures 9a to 9f. Although Figures 9a to 9f relate to the manufacture of a stacked EL element having two EL layers, the method can be applied to a stacked EL element having any number of EL layers.

The EL element 50 is grown on a substrate 51 on which is provided an anode electrode 52. In Figure 9a, a first inorganic alignment layer 53 is evaporated onto the anode electrode 52. The evaporation of the first alignment layer 53 is carried out such that the direction of evaporation is oblique to the substrate 50, and the alignment direction of the alignment layer will depend on the angle between the direction of evaporation and the substrate. This is well-known in the field of anisotropic materials such as liquid crystals.

In Figure 9b, a first EL emitter layer 54 is evaporated onto the alignment layer 53. The evaporation of the emitter layer 54 is carried out such that the direction of evaporation is substantially perpendicular to the substrate 50. The molecules of the emitter layer 54 will be aligned by the alignment layer 53, to be either parallel or perpendicular to the evaporation plane.

In Figure 9c, a second inorganic alignment layer 55 is evaporated onto the emitter layer 54. The evaporation of the second alignment layer 55 is carried out such that the direction of evaporation is oblique to the substrate 50. The angle between the direction of evaporation and the substrate is not the same in Fig 9c as in Fig 9a, so that the alignment direction of the second alignment layer 55 is not the same as the alignment direction of the first alignment layer 53.

In Figure 9d, a second EL emitter layer 56 is evaporated onto the second alignment layer 55. The evaporation of the second emitter layer 56 is carried out such that the

direction of evaporation is substantially perpendicular to the substrate 50. The molecules of the second emitter layer 56 will be aligned by the second alignment layer 55 to be either perpendicular or parallel to the evaporation plane, so that they are aligned in a different direction to the molecules in the first emitter layer 54.

Finally, in Figure 9e a cathode electrode 57 is evaporated onto the second emitter layer 56. The evaporation of the cathode electrode 57 is carried out such that the direction of evaporation is substantially perpendicular to the substrate 50. The structure of the completed EL element is shown in Figure 9f.

It would be possible for the anode layer 52 and the first alignment layer 53 to be combined in a single layer. This layer should be deposited by oblique evaporation, as shown in Figure 9a.

It is possible to provide additional transport layers between the anode electrode 52 and the first alignment layer 53, or between the second emitter layer 56 and the cathode electrode 57.

The method of Figures 9a to 9e can be used to grow stacked EL elements having 3 or more emitter layers. It is simply necessary for each emitter layer to be preceded by an obliquely evaporated alignment layer.

A further embodiment of the invention is illustrated in Figure 10. This is a one layer EL device, in which the emissive layer is divided into two regions.

It is also possible to alter the wavelength of light emitted by the emissive layer by orienting the emitter molecules. It is known that some emissive molecules show a change in their emission wavelength when they are orientated in an applied electric field. An example of such a compound is NIR (Nile Red), as reported by S. Nilar et al, "Journal of Applied Physics", Vol. 82, page 514 (1997). An EL device containing NIR will normally emit light having a peak wavelength of 578nm. If, however, the emissive

molecules are aligned to be perpendicular to the emissive layer, for example by applying an electric field, the emission wavelength changes to 521nm.

In the device shown in Figure 10, one part of the emissive layer, which contains NIR, has been subjected to an electric field to align the NIR molecules perpendicular to the emissive layer. The region 47 is then selectively fixed, to fix the NIR molecules in the perpendicular alignment. Upon removal of the electric field, the molecules in the unfixed region 48 will relax back to the parallel orientation. Thus, the region 47 of the light-emitting layer will emit light having a peak wavelength of 521nm, whereas the region 48 of the emissive layer will emit light having a peak wavelength of 578nm. If the two regions 47, 48 are controllable independently from one another, it is then possible to alter the output wavelength of the device just by switching, for example, region 47 OFF and region 48 ON.

The device shown in Figure 10 can also be produced using techniques which pattern surfaces into regions favouring homeotropic alignment and regions favouring planar alignment. Suitable techniques are described in co-pending UK patent application 9822762.2.

Devices according to the present invention can be manufactured by methods other than the methods described above. Indeed, they can be manufactured in principle by any method that will provide an electroluminescent layer that emits polarised light. Any method providing an oriented polymer, or an oriented organic material, could be used. For example, it could be possible to pattern the substrate such that the emissive molecules in the emitter layer are oriented by the patterns on the substrate as the emitter layer is deposited. Techniques that could be used include, but are not limited to, the following:

i) topographically patterned surfaces;

ii) masked, multiple rubbed polymer alignment layers, where one rubbing step is carried out on one un-masked portion of the layer, after which the rubbed portion is masked and another portion of the layer is rubbed in a different direction; and

iii) rubbing a polymer alignment layer, and subsequently exposing it to UV light through a mask so as to cause bond breaking in selected areas of the alignment layer.

Another possible method that could be used is to cross-link the emitter materials using polarised UV light to give a uniform alignment direction. This is a well-known technique, and is illustrated in Figure 11 which shows the cross linking of a cinnamate polymer under irradiation with polarised UV light.

The cross-linking of polymeric materials using polarised UV light to give a uniform alignment direction for the molecules is particularly useful for the alignment of an emitter layer in an organic EL device. These devices are often produced by sequential spin coating of several layers of material. In this case, it is important that mutually insoluble, exclusive solvents are used for the different polymer layers in the multi-layer device.

The well-known polymeric UV cross-linkable materials are deposited on a substrate before irradiation with UV radiation. The deposition can be carried out by, for example, spinning the materials down.

An alternative method is to deposit an anisotropically emitting liquid crystal polymer or LMM layer on top of a thin UV sensitive alignment layer that has been irradiated with polarised with UV radiation. The liquid crystal polymer may be oriented at a high temperature, and this forms an oriented glass at the temperature of operation of the device. The alignment layer should have as high a conductivity as possible, and be as thin as possible, to avoid adversely affecting charge transport in the device. The UV sensitive material used for the alignment layer may be a polymer that undergoes cross-linking, or some other change, under irradiation with UV light, or it could be a LMM compound with several reactive groups that are cross-linked under irradiation with UV light.

CLAIMS:

1. An electroluminescent device having first and second light-emitting regions, wherein the emitter molecules in the first light-emitting region are aligned substantially in a first direction and the emitter molecules in the second light-emitting region are aligned substantially in a second direction, the first direction being different from the second direction.

2. An electroluminescent device as claimed in claim 1 wherein the first light-emitting region emits, in use, light having a first polarisation and the second light-emitting region emits, in use, light having a second polarisation different from the first polarisation.

3. An electroluminescent device as claimed in claim 2 wherein the first and second light-emitting regions emit, in use, plane-polarised light.

4. An electroluminescent device as claimed in claim 3, wherein the plane of polarisation of light emitted by the first light-emitting region is at an angle of substantially 90° to the plane of polarisation of light emitted by the second light-emitting region.

5. An electroluminescent device as claimed in any preceding claim wherein the first light-emitting region emits light having a different wavelength to light emitted by the second light-emitting region.

6. An electroluminescent device as claimed in any preceding claim wherein the first and second light-emitting regions are disposed side by side.

7. An electroluminescent device as claimed in any one of claims 1 to 5 wherein the first light-emitting region is disposed over the second light-emitting region.

8. An electroluminescent device as claimed in claim 7 and further comprising a third light-emitting region, wherein the first region is disposed over the second region, and the second light-emitting region is disposed over the third light-emitting region.

9. An electroluminescent device as claimed in claim 8 wherein the third light-emitting region emits light having a third polarisation, the third polarisation being different from at least one of the first and second polarisations.

10. An electroluminescent device as claimed in claim 9, wherein the first, second and third light-emitting regions emit plane-polarised light, the plane of polarisation of the light emitted by the second light-emitting region being at substantially 60° to the plane of polarisation of light emitted by the first light-emitting region, and the plane of polarisation of light emitted by the third light-emitting region being at substantially 120° to the plane of polarisation of light emitted by the first light-emitting region.

11. An electroluminescent device having a first light-emitting region for emitting light having a first polarisation and a second light-emitting region for emitting light having a second polarisation different from the first polarisation.

12. An electroluminescent device substantially as described herein with reference to any one of Figures 3, 4, 5a, 6, 7, 8, 9f or 10 of the accompanying drawings.

13. A method of manufacturing an emitter region for an electroluminescent device, the method comprising the steps of:

disposing emissive molecules in a fluid matrix;

aligning the emissive molecules within the matrix; and

fixing the matrix, so as to hold the alignment of the emissive molecules within the matrix.

14. A method as claimed in claim 13, wherein the step of aligning the emissive molecules comprises applying an electric field.

15. A method as claimed in claim 14, wherein the step of aligning the emissive molecules comprises applying a magnetic field.

16. A method as claimed in any of claims 13 to 15, wherein the step of fixing the matrix comprises fixing only a selected portion of the matrix.

17. A method of manufacturing an emitter region for an electroluminescent device, the method comprising the steps of:

evaporating an alignment layer over a substrate, the direction of evaporation being oblique to the substrate; and

evaporating emissive molecules onto the alignment layer so as to form the emitter layer, the direction of evaporation of the emissive molecules being substantially perpendicular to the substrate.

18. A method of manufacturing an electroluminescent device substantially as described herein with reference to Figures 9a to 9e of the accompanying Figures.

20

The Patent Office

INVESTOR IN PEOPLE

Application No: GB 9827328.7
Claims searched: 17

Examiner: Martyn Dixon
Date of search: 20 April 1999

Patents Act 1977
Further Search Report under Section 17

Databases searched:

UK Patent Office collections, including GB, EP, WO & US patent specifications, in:

UK Cl (Ed.Q): H1K (KEAL,KEAM)

Int Cl (Ed.6): H01L (33/00,51/00,51/20,51/40); H05B (33/12,33/14): G02F (1/337)

Other: online: EPODOC,WPI,JAPIO,INSPEC

Documents considered to be relevant:

Category	Identity of document and relevant passage	Relevant to claims
A	EP 0712024 A (Seiko)	17

X	Document indicating lack of novelty or inventive step	A	Document indicating technological background and/or state of the art.
Y	Document indicating lack of inventive step if combined with one or more other documents of same category.	P	Document published on or after the declared priority date but before the filing date of this invention.
&	Member of the same patent family	E	Patent document published on or after, but with priority date earlier than, the filing date of this application.

21

The Patent Office

INVESTOR IN PEOPLE

Application No:	GB 9827328.7	**Examiner:**	Martyn Dixon
Claims searched:	13-16	**Date of search:**	20 April 1999

Patents Act 1977
Further Search Report under Section 17

Databases searched:

UK Patent Office collections, including GB, EP, WO & US patent specifications, in:

UK Cl (Ed.Q): H1K (KEAL,KEAM)

Int Cl (Ed.6): H01L (33/00,51/00,51/20,51/40); H05B (33/12,33/14)

Other: online: EPODOC,WPI,JAPIO,INSPEC

Documents considered to be relevant:

Category	Identity of document and relevant passage		Relevant to claims
X,Y	GB 0788479 A	(Westinghouse) see especially page 2, lines 70-92	X:13,14 Y:15
X,Y	WO 98/35393 A	(Commissariat a l'Energie Atomique) see e.g. page 1, lines 5-9 and page 17, lines 22-34	X:13,14 Y:15
X	WO 97/07654 A	(Philips) see e.g. page 5, lines 27-32	13
Y	EP 0786820 A	(Motorola) see col 5, lines 6-27	15

X	Document indicating lack of novelty or inventive step	A	Document indicating technological background and/or state of the art.
Y	Document indicating lack of inventive step if combined with one or more other documents of same category.	P	Document published on or after the declared priority date but before the filing date of this invention.
&	Member of the same patent family	E	Patent document published on or after, but with priority date earlier than, the filing date of this application.

22

The Patent Office

INVESTOR IN PEOPLE

Application No: GB 9827328.7
Claims searched: 1-12

Examiner: Martyn Dixon
Date of search: 9 March 1999

Patents Act 1977
Search Report under Section 17

Databases searched:

UK Patent Office collections, including GB, EP, WO & US patent specifications, in:
UK Cl (Ed.Q): H1K (KEAL,KEAM)
Int Cl (Ed.6): H01L(33/00,51/00,51/10,51/20,51/30,51/40); H05B (33/12,33/14,33/20)
Other: Online: EPODOC,WPI,JAPIO,INSPEC

Documents considered to be relevant:

Category	Identity of document and relevant passage		Relevant to claims
A	GB 0788479 A	(Westinghouse) see the whole document	
A	WO 97/07654 A	(Philips) see the whole document	
A	WO 96/03015 A	(Forskarpatent I Linkoping) see example 2 and figs 2-6	

X Document indicating lack of novelty or inventive step
Y Document indicating lack of inventive step if combined with one or more other documents of same category.
& Member of the same patent family
A Document indicating technological background and/or state of the art.
P Document published on or after the declared priority date but before the filing date of this invention.
E Patent document published on or after, but with priority date earlier than, the filing date of this application.